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Remote Sensing of Natural Areas: Procedures and Considerations for Assessing Vegetation Composition Change, Land Development, and Erosion

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Introduction

Remote sensing can be defined as the "acquisition and measurement of data/information on some property(ies) of a phenomenon, object, or material by a recording device not in physical, intimate contact with the feature(s) under surveillance" (Short 1997). Scientists utilizing remote sensing are able to collect vast quantities of data quickly and efficiently for rapid analysis. In the last Technical Report, we provided an introduction to how remote sensing can be used for detecting vegetation stress and pollution. Remote sensing can be used for more far-ranging applications. In this report, we will discuss how remote sensing can be used to monitor vegetation changes, land development, and erosion in natural areas. As with stress detection and pollution, the data collected, and the sensors used to collect it, depends primarily on the user's purpose for the data.

Vegetation Composition Change

In order to use remotely sensed data to measure changes in vegetation over time, one must first be able to identify the relevant groups or species to be observed. The simplest method involves visually interpreting the images. Multitemporal images, images taken over the same area over a period of time (ranging from within the same day to years), can reflect changes in the vegetation to an analyst. Stereograms, photographs taken along the same flight strip that overlap by at least 50%, allow scenes to be viewed in three dimensions with the aid of a stereoscope. This device can aid the interpreter in determining landscape changes (Lillesand and Kiefer 1994). This technique works well with data taken by conventional color and color-IR photography. The interpreter can use features in the photograph such as shape, size, tone, shadow, patterns, and texture to discriminate different types of vegetation. As discussed previously, the scale of the photograph is important. For example, determining changes along a shoreline becomes difficult at a scale of 1:10 000, as features become difficult to discern (Barrett and Curtis 1992).

Another method involves classifying the data with the aid of a computer. Images taken digitally, such as with the DMSV, are composed of many pixels, or dots. Each pixel represents some area on the ground. The amount of area contained within each pixel depends on the type of sensor used and the height of the sensor above the ground. For example, digital imagery taken with the DMSV is composed of 740*578 pixels, or 427,720 pixels overall. Each pixel is assigned an 8 bit brightness value, or digital number, ranging from 0 to 255 that is a measure of how 'bright' the area appears to the sensor. A brightness value of 0 means that sensor recorded no light from an area, or that light levels were below detectability. A brightness value of 255 means that sensor received the maximum amount of light that it could detect. The DMSV is comprised of four separate cameras that each photograph the same area. Each camera is outfitted with a different filter that allows it to sense only a certain part of the EMS. As a result, it is capable of recording four data (four separate wavelengths in the EMS) for each pixel. Bandpass interference filters allow the DMSV to acquire data in the blue, green, red, and infrared wavelengths simultaneously. The exact region of the EMS for each color is called a 'band.' People can not see infrared light directly. In order to see information from that band, the analyst must assign a different color to it. An analyst can combine the colors red, green, and blue to form an image. This means that the analyst can only view three bands at a time if they wish to view a color composite of the digital image. In viewing one band, the computer can simply assign shades of gray to the brightness value of that band (0=black, 255=white). To assign colors, red, green, and blue are used. For example, if the blue, green, and red bands are assigned to the colors *blue, red, and green*, all plants in the scene will look red. Such an image, in which bands are not marked as their actual colors, is called a 'false-color' image.

Satellite instruments, which contain more sensors, can record information from more bands. These can be entered as data into a computer for classification, or grouping, into several classes depending on the user-defined goals. Each pixel within the image is assigned to a particular class. The computer analyzes the different bands and groups the most closely associated pixels together with each other. There are several different mathematical methods that the computer is able to use to classify the imagery, but the goal is essentially the same: to distinguish and present on one image the different types of vegetation. A thematic map, or map composed of different colors visible to the naked eye, is usually overlaid on top of the original image to clarify the position of different classes.

Groundtruthing is essential for performing a good classification. The computer can separate pixels into different classes, but only the interpreter can give those classes meaning. Every pixel's precise digital numbers may be different. The classification can be supervised or unsupervised. In unsupervised classification, the computer clumps similar pixels together, with 'similar' being decided by the mathematical formula used, such as the 'minimum-distance-to-means classifier' or 'parallelepiped classifier.' The producer must determine, using groundtruthed data, which groups represent different species, or which groups are artifacts of statistical analysis. Supervised classification involves analyst identification of certain pixels. The computer examines those pixels, determines their charactistics, and classifies all unidentified pixels based on the traits of the identified pixels. The known pixels are referred to as 'training areas.' (Lillesand and Kiefer 1994). After an image is classified, the procedure for interpretation is the same as if it were being visually inspected, except that the computer is able to determine changes in area over time more precisely.

There is also the issue of accuracy with classification. The computer may misinterpret the data. Vegetation that belongs in one class may be classified as another. An error matrix is one means of interpreting the possible errors of a classification. It is a comparison of the actual values that a pixel represents against the computer's interpretation of the image. Groundtruthing, or training set data used in supervised classifica-

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tion, provides the necessary information from which to make this judgment. Measures such as the overall accuracy can be derived from this matrix. The overall accuracy is the total number of correctly classified pixels in an image, divided by the total number of pixels. Errors of commission and omission are other measures of accuracy that can be derived from the matrix, and are used, respectively, by the user and producer of the data (Lillesand and Kiefer 1994).

The detail required in a vegetation composition study depends on the requirements of the study. If someone does not require very accurate data, photographs of different scales from different time periods can be utilized without much risk of making a serious error. However, if a study requires a detailed analysis, such as in a study of the expansion of an exotic species' range over time, high resolution, high scale imagery will be required, as the exotic may exist as only a single individual in a recent image. As the scale decreases, individual spectral reflectance values become merged with others, as a single pixel incorporates all the spectral data from within a larger space. Where a large scale image might incorporate the spectral reflectances from 10 plants, a smaller scale image might incorporate 100 plants. The formula used in classifying the data may also affect the final thematic image.

Encroaching Land Development and Erosion

The procedures for observing encroaching land development are similar to those in identifying vegetation compositional changes. The goal is to determine where development is approaching and impacting natural areas. Photographs taken from different time periods, and at different scales, can give a measure of the impact of development on the ecosystem. The smaller the scale, the larger the area one is examining for signs of change. Whereas determining vegetation composition change requires detailed knowledge of the different species in an image, determining the effects of development may only require knowledge at broader levels, such as shift from wetland to upland vegetation. These distinct classes may have different spectral reflectance characteristics. In addition, the development itself may be visible in the imagery. Signs of stress in nearby vegetation would indicate that development is having an impact on wetland ecosystems.

Over time, signs of erosion along a coastline can become visible to individuals utilizing remote sensing techniques. Rather than spending excess time surveying a coastline, remote sensing gives a quick and effective way of measuring changes by providing the observer with the means to tell at a glance what effects erosion is having on the shape of the coastline. If precise studies are required on the rates of sediment removal, groundwork might be required, but rough estimates could be obtained by examining photographs taken over time. These changes would be visible with color or color IR photographs, or digital equipment such as the airborne visible-IR imaging spectrometer (AVIRIS) (Hardisky *et al*. 1986). Satellite imagery, such as that taken by SPOT or the TM sensors, would also be useful. Changes in the shape of a coastline would be clearly visible through visual comparison of photographs taken at different times; computer analysis would likely not be necessary. If a precise estimate of erosion rates was needed, images could be scanned into a computer, which could be analyzed for the change in land mass lost (or gained). Computer analysis can also be made more accurate through the use of algorithms such as temporal image differencing. When using any imagery for change detection analysis, images taken at approximately the same time of year is preferred (Lillesand and Kiefer 1994). This helps to eliminate any seasonal differences in land cover.

Conclusions

In our last discussion, we discussed how remote sensing is useful for monitoring stress and pollution. Remote sensing is also an excellent tool for monitoring changes in vegetation composition and detecting signs of development and erosion. As we described, it does have limitations that managers and scientists need to be aware of. The resolution of the image and the time over which the data was collected are just two of the factors that can affect data interpretation and use. Remote sensing can save time and effort in performing initial surveys or monitoring studies, and can, depending on the resolution and type of equipment used, be an effective way of conducting a study with results better or as good as more traditional techniques.

Note: CERSP maintains a database on the functional comparison of created and natural wetlands at http://www.vims.edu/rmap/cers/

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